Unattended Ground Sensors
A Prospective for Operational Needs and Requirements

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1. Introduction

The awareness and use of passive sensor technologies for remote battlefield applications has greatly increased over the last few decades. Advances in digital signal processing (DSP) have spawned faster yet smaller and low-power computer chips that provide an opportunity for executing computationally extensive algorithms in real time. These advances have made the development of practical unattended ground sensors (UGS) possible. They can exist in various sizes and forms, contain several sensor technologies, can be deployed by several means, and can report information on or about different types of targets.

UGS consist of a variety of sensor technologies that are packaged for deployment and perform the mission of remote target detection, location and/or recognition. Ideally, the UGS are small, low cost and robust, and are expected to last in the field for extended periods of time after deployment. They are capable of transmitting target information back to a remote operator. These devices could be used to perform various mission tasks including perimeter defense, border patrol and surveillance, target acquisition, and situation awareness. UGS can be designed to locally process target information, such as detection, bearing estimation, tracking, classification and/or identification. They can also be used for reporting battle damage assessment (BDA) in standoff strike scenarios. In order to support the varied missions of UGS systems, robust and reliable communication links must provide timely message transmissions back to a command and control (C2) center. Optimum performance of UGS systems is based on terrain, weather, and background noise estimates. Select computer models are used to predict performance and identify optimal deployment sites.

Various UGS have been designed and deployed by NATO countries. It may be desirable to concatenate mission needs and device capabilities, and to standardize information for various UGS.

2 Characteristics of UGS

Devices may consist of a battery-powered, single or multiple co-located sensors, with signal processing capability to analyze target characteristics, and transmit target recognition information to a remote monitoring location. UGS can be deployed by one of many different techniques. Miniaturization and cost reduction of components is a high priority, to facilitate packaging into artillery projectiles, large deployment from an airborne target or from a launched canister, or hand placement. Artillery and air deployment requires UGS and electronics to be highly robust, shock resistant and weather proof.

The operational life of UGS can be greatly extended with smart power management, which can extend the useful life of the device beyond that of normal, continuous operation. Smarts could be designed into the electronics to monitor the environment every several seconds with minimum power requirement. Once target detection is established, the UGS could power themselves up for normal real time monitoring operations.

Typical UGS have limited ranges of detection and identification. These limitations are generally due to background noise or weather and diurnal changes. A need exists to deploy several UGS devices in the vicinity of one another to ensure continuous monitoring of detected targets. A network of nodes that uses multiple sensor technologies can accurately locate and identify battlefield targets. In addition, they can perform valuable BDA by monitoring activities before and after each attack. UGS should be made as affordable as possible. Cost can become an issue if the price of any one of these devices gets too high. Smart packaging of UGS in addition to self-location and orientation of sensors greatly improves their performance capability for deployment. Sensor fusion capability at the device level greatly enhances the probability of detection and probability of correct identification of target over range. Sensors built within UGS are generally passive in nature and can include acoustic, seismic, magnetic and IR capability. Correlation of features from various sensor technologies greatly enhances the target-recognition capability.

A robust communication link is key to a successful remote deployment of UGS, for without it, robust target measurements could not be extracted for monitoring. Communication bandwidth and transmission power should preferably be low. Data compression and data encryption could be used for secure Low Probability of Intercept (LPI) and Low Probability of Detection (LPD).

3 Information Processing

The targets of interest generally depend on the mission plan. For battlefield applications, detection of personnel (troops on the move), ground targets (single and multiple vehicles in convoys), airborne targets (helicopters, jets, cruise missiles, UAVs), and transients (missile, gun, mortar or artillery or sniper fire) could be significant events of interest. The most mature, low-cost, passive sensor technologies for UGS applications are acoustic, seismic, magnetic, and optical technologies. Target detection, tracking, localization, and recognition is vital information UGS can determine from network of sensors. Sensor fusion is the key to the fidelity and accuracy of UGS. Robust target information can be obtained through fusing information obtained from the different sensor types co-located on the same UGS. Higher-level sensor fusion, including information from different UGS can also improve performance. For example, fusing acoustic, seismic and IR information can improve classification and identification, and fusing bearing information from different UGS could be used to triangulate and estimate target location.

Advancements in DSP/CPU technology have made application of state-of-art signal processing possible for UGS. Traditional stochastic and statistical signal processing techniques, used by the Navy for underwater applications, have been successfully applied. However, due to the non-stationary nature of the signals, changing environment conditions, and a variety of target scenarios, there are fundamental limits on how well UGS can perform. The key is to be able to predict and quantify UGS performance under different sets of conditions.

Once a report is formed at the system level, it is transmitted back via short or long haul communication to a display, where the information is monitored. A-priori knowledge of weather and terrain information is key to successful interpretation of the information received. Decision aid models can be run to provide statistical tolerances on the type of information received from each UGS deployed. Sensor performance models can also be run to estimate the accuracy of detected targets.

4 Operational Requirements

- Passive sensors
- Low cost / small / inexpensive
- Wide area coverage
- Robust / weather proof
- Target recognition
- Remote monitoring / reprogramming
- Long life span (depending on mission)
- Robust communication with LPI / LPD
- Protection against tampering

UGS are used to support various military operations, based on the design and method of deployment. Most important is the concept of providing information access to remote and denied areas in tactical surveillance zones. The UGS capability of autonomously monitoring remote terrain provides an accurate picture of the area where sensors are deployed. UGS provide maneuver commanders with a continuous, near-real-time source of information on enemy movements. They offer the ability to confirm information obtained from other sources and to obtain information in areas where conditions render other systems ineffective. This improved situational awareness offers commanders a standoff strike capability, by attacking with precision munitions, artillery, or other (type) fires.

The deployment of a distributed sensor field can help the commander disrupt the enemy's capacity to attack. By recognizing targets sooner, units can maneuver and deploy large amount of munitions more effectively. In addition, UGS can be deployed to enhance early entry-force survivability, perform defensive security, and provide flank protection and security.

Clearly, an important mission for UGS is early-warning remote target recognition and surveillance. Once deployed, UGS activate themselves by responding to commands for initialization. Sensors cueing one another, remote reprogramming and smart sensors could be a few of the many functions designed to enhance situational and forward area awareness, as well as rear-area protection. Mass insertion is facilitated by low-cost, small size, and multiple deployment options (hand, air, munitions). This rapidly deployable area monitoring system provides revolutionary advances in operational effectiveness. The reported information the system provides includes troop and vehicle movements, munitions activity, critical choke point access, entry point activity (littoral, building etc.), and cleared area monitoring knowledge to multiple levels of users, i.e,. individual soldiers, squads, Tactical Operation Center (TOC). The benefits to the warfighters are endless. Providing an extension of the individual soldier's senses (acoustic, optical, chemical, seismic, etc.) for threat detection greatly enhances his ability for surveillance and perimeter defense application.

5 Existing Systems

Various types of UGS exist around the world and are used for various missions. The following are just a sample of systems that are under research or being used in the field. Note that the information provided may not be an exact description of the capability:

- In Canada, work is ongoing on a sniper location system called GUARDIAN, which was designed as an area-monitoring device to equip observation posts for perimeter defense. The system uses acoustic sensors to detect sniper fire, and estimates the azimuth and elevation of the shooter.

- In Denmark, UGS are used for route and area surveillance. Acoustic and seismic sensors are deployed to estimate ground vehicle movement and locate explosion events.

- In France, various mature systems have been developed especially for sniper detection. Select sensors, including a combination of acoustic, IR, and lasers, are combined to detect and estimate azimuth and elevation of detected snipers. In addition, work is ongoing to develop UGS for ground vehicle detection.

- In Germany, a system called BSA has been developed with the capability of detection, classification, and type identification of personnel and ground vehicles. Several sensors are combined to improve on the probability of detection and classification, including acoustic, seismic and magnetic, IR, and pyroelectric.

- In the Netherlands, a suite of UGS is available for various missions, including personnel and ground vehicle detection for open field and perimeter defense applications. The Footfall detector uses seismic sensors for personnel detection. The Monitor of Enemy Movement (MEMO) is a system designed for detection of personnel, in addition to ground vehicles (wheel or track). The MEMO is networked, using communication links, back to a monitoring station.

- In the UK, a system called HALO is used to monitor artillery fire. A few unattended acoustic and met sensors are deployed for long-range detection of a transient signal emanating from artillery fire. Bearing information is extracted from the various UGS and transmitted to estimate source location.

- In the U.S., a system called the REMote Battlefield Acoustic and Seismic System (REMBASS) was originally developed in the early ‘70s. This system uses acoustic, seismic, and magnetic sensors to estimate target detection and classification. Since then, an improved (REMBASS), IREMBASS, was fielded with enhanced performance. In the late ‘80s, the wide area munition (WAM) was developed. Sensors onboard include an acoustic array of microphones and a seismic sensor. The WAM detects, estimates target bearing and range, and deploys a munition to kill the target when it is at the closest point. Another concept, developed in the ‘90s is called the inter-netted unattended ground sensor (IUGS). Designed to be air deployed, the IUGS contains a suite of co-located sensors such as acoustic, seismic, magnetic, met, and IR sensors. Follow-on to that program is the Micro IUGS or MIUGS. This system is simply a miniaturized version of the IUGS. Both of these systems are networked to estimate the location and identification of ground and airborne targets.

It is no surprise that many of the above countries have benefited from the advantages UGS can provide for long-range detection, tracking, localization, and identification of various types of targets. A need exists to standardize the mission of UGS among the NATO partners to ensure interoperability of information and components.

6 Conclusion

The concept of unattended ground sensors is an emerging technology that is gaining worldwide attention. These systems potentially offer both the field commander and the headquarters staff the capability of battlefield early warning and situational awareness. Future development promises low-cost, robust systems of small size that can be deployed by many means. Their potential stealth and networked intelligence will further enhance battlefield effectiveness. These systems are capable of diverse mission operations, such as target recognition, perimeter defense, surveillance, and flank protection, while providing a quantum leap in situational awareness.

With the endless possibilities of capabilities and benefits comes a need to ensure compatibility between NATO systems. Currently, various NATO countries employ some form of UGS, either for transient (event) location or for ground or airborne target detection. It is the objective of this paper to demonstrate the potential operational requirements and the need for standardization between the emerging NATO systems.